Damping Detection for Periodic Bridge Health Monitoring using a Moving Vehicle

McGetrick, P., Kim, C. W., González, A., OBrien, E. J., & Kawatani, M. (2012). *Damping Detection for Periodic Bridge Health Monitoring using a Moving Vehicle*. Paper presented at 14th Japan Society of Civil Engineers (JSCE) International Summer Symposium, Nagoya, Japan. http://www.jsce-int.org/event/symposium/ss15

Damping Detection for Periodic Bridge Health Monitoring using a Moving Vehicle

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1. Introduction

In the past decade there has been a considerable increase in the number of bridges being instrumented for the purposes of vibration based monitoring, typically to monitor dynamic parameters such as frequencies and mode shapes. This type of approach using direct measurements can be very accurate and provide valuable information about a bridge structure. However, drawbacks of this approach include the time and expense associated with the installation of sensors and data acquisition equipment on the bridge. Also, although short to medium span bridges form the greatest proportion of transport networks worldwide, a large percentage of these are not instrumented.

Therefore, more recently, a number of researchers have investigated the use of an alternative low-cost approach to monitor bridge dynamic parameters which involves the use of a moving vehicle fitted with accelerometers on its axles. By taking measurements on the vehicle only, this type of indirect method reduces the need for direct installations on the bridge. It is therefore aimed at providing an efficient alternative for the preliminary screening of the condition of short to medium span bridges' in a transport network.

In this paper, the feasibility of use of the instrumented moving vehicle to detect changes in bridge damping is investigated in a laboratory experiment. The damping of the bridge is used as a damage indicator in this paper as it has been shown to be damage sensitive[1,2]. Furthermore, it has been found in numerical investigations that it is possible to detect changes in bridge damping from the acceleration response of an instrumented vehicle[3,4]. The experimental setup and results are described in the following sections.

2. Experimental Setup and Methodology

Figure 1 shows a longitudinal view of the experimental setup. The scaled bridge is a 5.4 m simply supported steel beam with a natural frequency of 2.7 Hz which also incorporates a road profile while a two axle vehicle model is used. Three different vehicle configurations and speeds were tested in a preliminary analysis. The results for the optimal vehicle model and speed (0.93 m/s) are presented in this paper. This vehicle model has a mass of 21.35 kg and bounce and pitch frequencies of 2.93 Hz and 4.24 Hz respectively. The damping of the bridge is varied artifically using old displacement transducers at locations marked in Figure 1; the specific configurations chosen for this experiment are 'C' and 'ABCDE' repectively. An additional mass of 17.8 kg is also added at midspan to account for a change in frequency that can occur with a change in damping.

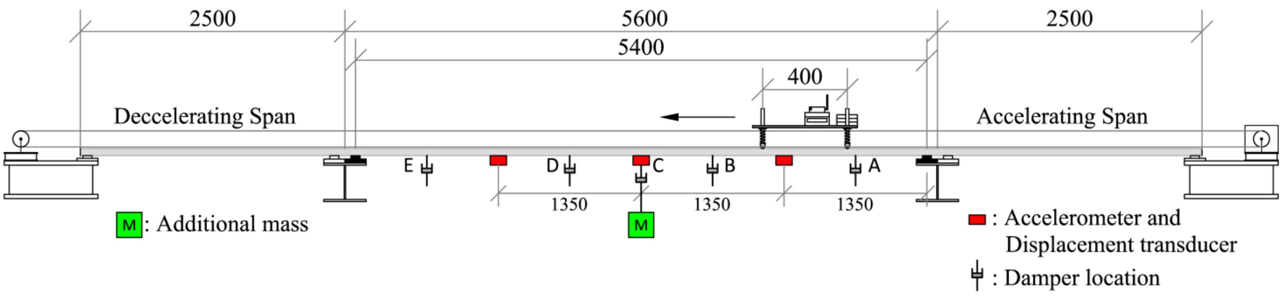

Figure 1 Experimental Setup

3. Results and Discussion

Figure 2 shows an example of the spectra of bridge and vehicle accelerations for all damping scenarios investigated. Results are shown for a vehicle speed of S1 = 0.93 m/s. This figure shows that for increased damping, the magnitude of the bridge acceleration spectra decreases at the bridge frequency peak of 2.54 Hz. A decrease in peak magnitude also occurs at the corresponding peak at 2.44 Hz in the vehicle spectra which suggests the change in damping can be detected. The change in magnitude also occurs at the body pitch frequency peak of 3.91 Hz.

Keywords: bridge, monitoring, damping, frequency

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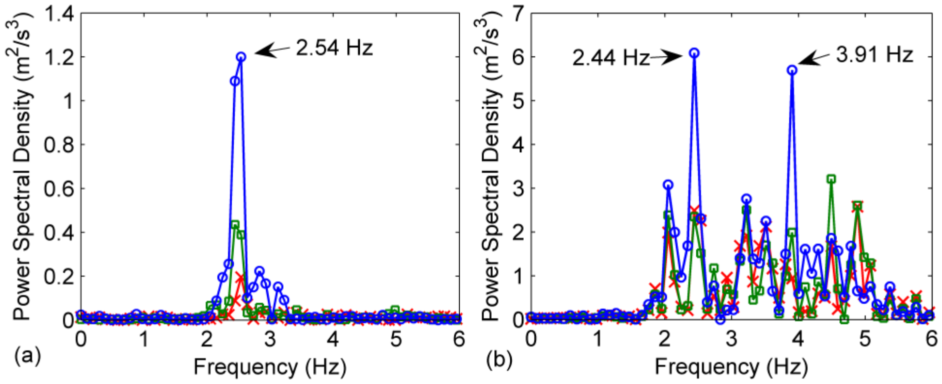

Figure 2 Spectra of accelerations for (a) bridge midspan (b) rear axle of vehicle for speed S1. Scenarios: (○) Intact, (□) C, (×) ABCDE.

To confirm if the vehicle is sensitive to changes in damping, the percentage change in area under the spectra curves calculated between the intact scenario and scenarios C and ABCDE respectively is used as a measure of sensitivity. The calculated values are shown in Figure 3. It can be seen that for an increase in damping, the area under the PSD curve decreases for the bridge, corresponding to a reduction in vibration energy. It is observed that both vehicle axles are highly sensitive to a change in damping and also detect the increase from scenario C to ABCDE. For example, for an increase in damping ratio from the intact scenario (0.016) to C (0.027), the percentage change in area for the rear axle is approximately 27%. Also, although the changes in damping investigated here were quite large the results nevertheless serve to illustrate the sensitivity of the vehicle to those changes.

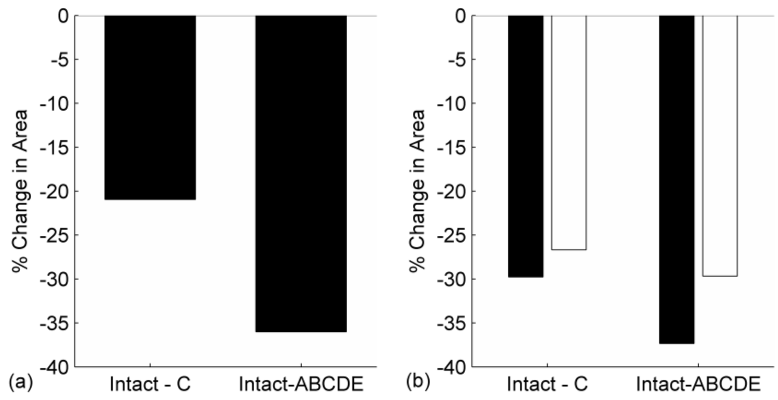

Figure 3 Sensitivity to damping ratio changes for accelerations (a) Change in area under bridge acceleration spectra (b) change in area under front axle (■) and rear axle (□) acceleration spectra for vehicle.

4. Conclusions

This paper has presented an experimental investigation of the use of an instrumented vehicle to detect changes in the damping of a bridge. In the laboratory experiments it has been observed that changes in bridge damping can be detected easily in the bridge acceleration spectra but they are more difficult to identify in the vehicle acceleration spectra. It has been found that by analysing the area under the acceleration spectra curves of vehicle acceleration spectra, the vehicle is very sensitive to changes in the experimental bridge damping ratio. These results indicate the feasibility of periodically monitoring the damping of short to medium span bridges using the instrumented vehicle.

5. References

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